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**FACULTY WORKING PAPER 93-0158**

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# Foreign Direct Investment, Exchange Rate Variability and Demand Uncertainty

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# **BEBR**

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## **Foreign Direct Investment, Exchange Rate Variability and Demand Uncertainty**

Linda S. Goldberg

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## Abstract

Variable real exchange rates influence the country chosen for location of production facilities by a multinational enterprise. With risk averse investors and fixed productive factors, a parent company should not be indifferent to the choice of production capacity location, even when the expected costs of production are identical across countries. If a non-negative correlation exists between real export demand shocks and real exchange rate shocks, the multinational will optimally locate some of its productive capacity abroad. The share of production capacity located abroad increases as exchange rate volatility rises and also rises as exchange rate and export demand shocks become more correlated. These results are supported by empirical analysis of quarterly United States bilateral foreign-direct-investment flows with Canada, Japan, and the United Kingdom: exchange rate variability is associated with a rise in the share of production capacity located offshore.

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## I. INTRODUCTION

The importance of exchange-rate variability for domestic and international investment flows has been argued in numerous contexts. In industrialized economies, the purported effects of exchange-rate variability have influenced the choice of international monetary regimes. This issue arose in the early 1970s when the Smithsonian Agreement was discussed and again at the time of the Plaza Accord during the mid-1980s. In the early 1990s, the posited negative implications of variable exchange rates was one motivating theme in designing the Exchange Rate Mechanism (ERM) that aspired to guide currencies within the European Monetary System. The currency crises within the ERM in September 1992 and Spring 1993 refocused attention on the rationale for limiting exchange rate movements and on validity of arguments that exchange rate variability is costly and dampens real economic activity.

To date, much of the analysis of the real effects of variable exchange rates has considered whether variable exchange rates depress domestic exports and thereby worsen international competitiveness. Empirical tests over both developed and developing country export data have reached ambiguous conclusions.<sup>1</sup> Other recent discussions of the additional costs of variable exchange rates center on the expense of: irreversible investment decisions, over-investment in productive capacity, and exchange-rate-induced incentives for domestic producers to located their manufacturing facilities outside of the United States.<sup>2</sup> As in the literature on hysteresis in trade [Dixit (1989), Baldwin and Krugman (1989)], an important issue is whether transitory movements of exchange rates may lead to persistent restructuring if not deindustrialization of economies and whether this restructuring is stimulated or reduced when future exchange rates are uncertain.

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<sup>1</sup>Edison and Melvin (1990) provide a critical survey of this literature.

<sup>2</sup>Goldberg (1993) examines quarterly real investment activity in 31 sectors of United States industry and finds that in the 1980s real exchange rate variability is correlated with reduced investment activity. Campa and Goldberg (1993) conclude that the depressing effects of exchange rate volatility on United States investment have varied over time in relation to sectoral reliance on export markets and imported inputs into production. These results are most significant for durable goods sectors.

In this paper we explore the implications of exchange rate variability for foreign direct investment (FDI) flows. Our main theoretical result shows that if exchange rate variability is to have a real impact on foreign direct investment, it will work in the direction of increasing the share of production activity that is located offshore. For these results, we consider the decisions made by risk-averse managers who are faced with both revenue and cost uncertainty. Our theoretical propositions are tested using United States bilateral FDI data for the 1978 to 1991 period. The empirical findings support the main theoretical results.

The international *investment* implications of variable exchange rates, often stated in policy discussions, have not been the subject of much formal analysis. The theoretical work on this subject is divided among production flexibility arguments and risk aversion arguments. The production flexibility arguments have been expounded most recently by Aizenman (1992).<sup>3</sup> Aizenman relies on a production structure whereby producers commit to domestic and foreign capacity *ex ante* and commit to employment decisions *ex post*, following the realization of some stochastic element such as nominal or real shocks. The theoretical results are an open-economy extension of the earlier literature on domestic investment, wherein the effects of price variability on investment hinge on the sunk costs in capacity (i.e. the extent of investment irreversibilities), on the competitive structure of the industry, and overall on the convexity of the profit function in prices.<sup>4</sup> In the production flexibility arguments, the important presumption is that producers can adjust their use of a variable factor following the realization of a stochastic input into profits.

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<sup>3</sup>In the international context, de Meza and van der Ploeg (1987) also have explored the "production-flexibility motive" behind the plant location decisions of a multinational enterprise, arguing that the structure of marginal-cost shocks and demand elasticities are key determinant of optimal investments in domestic and foreign capacity.

<sup>4</sup>The linkage between investment and price variability has been explored in a distinct domestically-oriented literature. See Hartman (1972), Abel (1983), Craine (1989), Pindyck (1988) and Caballero (1991).



Without this variable factor, i.e. under a productive structure with fixed instead of variable factors, the potentially desirable effects on profits of price variability<sup>5</sup> are diminished.

An alternative approach linking exchange-rate variability and investment relies on risk aversion arguments. One treatment of this argument emphasizes that higher exchange-rate variability lowers the certainty equivalent expected exchange-rate level.<sup>6</sup> These certainty equivalent levels are used in the expected profit functions of firms that make investment decisions today in order to realize profits in future periods.<sup>7</sup> Alternatively, one could directly model the utility of expected profits as decreasing in their variability, as we have done in Section II.<sup>8</sup>

These production flexibility versus risk aversion approaches have merit under different circumstances. The most important determinant is the time horizon between the investment in capacity and the realization of the exchange rate shock. Specifically, when considering whether exchange rate variability has real effects, a clear distinction must be made between short term exchange rate volatility and longer term misalignments of exchange rates. For sufficiently short horizons, *ex ante* commitments to capacity and to related factor costs are a more realistic assumption than introducing a model based on *ex post* variable factors of production.<sup>9</sup> Hence, when considering the effects of short-term exchange rate variability, risk aversion arguments are more convincing than production flexibility arguments. For variability assessed over longer time horizons, the production

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<sup>5</sup>This effect is based on the strength of the Jensen's inequality argument leading to profit convexity in variable prices.

<sup>6</sup>See Cushman (1985, 1988).

<sup>7</sup>Another recent theoretical argument about the linkage between exchange-rate movements and investment is based on the premise of imperfect capital markets [Froot and Stein (1991)]. In this setting, exchange rate movements alter the relative wealth positions of competing international investors. By contrast, the emphasis of our paper is on the foreign direct investment effects of forecast exchange rate *variability*, instead of on contemporaneous exchange rate levels.

<sup>8</sup>See also Wolak and Kolstad (1991) who examine the covariance among different exchange rates in a portfolio type analysis.

<sup>9</sup>Another explanation is that the technology is such that capacity is fully utilized.

flexibility motive provides a more compelling rationale for foreign direct investment flows to be sensitive to variable exchange rates.

We are concerned in this paper with the implications of higher frequency exchange rate variability than that appropriate for the production flexibility arguments. This higher frequency exchange rate variability (for example, over weekly or monthly data) is the type of movement that is typically considered in less rigorous discussions of the real effects of exchange rate movements. Thus, our theoretical exposition relies more heavily on those arguments based on aversion to the volatility of profits.

In Section II, using a two-period model of the inter-temporal decision-making of a producer, we demonstrate how current assessments of future exchange-rate variability determine the portion of future market demand to be satisfied by production facilities situated in domestic versus foreign economies. Due to the emphasis of our model on short run activity, we do not permit *ex post* adjustment of a variable productive factor: producers cannot fire or hire workers the moment that they observe the realization of the stochastic exchange rate or of demand. With labor contracts, most factors are quasi-fixed in the production function.

If the parent company is risk neutral and if we assume that exchange rate movements do not influence *expected* production costs, the parent company is indifferent to the location of its manufacturing facilities. By contrast, if the parent has even a small degree of risk aversion, the location of production facilities matters. The actual division of capacity across borders depends on the distributions of both exchange rate and demand shocks, and more generally, on whether the export market is more likely to experience monetary or real shocks.

In Sections III and IV the theoretical propositions are examined empirically using data on quarterly bilateral foreign direct investment flows between the United States and the United Kingdom, Canada and Japan. The estimation interval spans from 1978 through 1991. The effects on FDI of real exchange rate variability, real foreign demand shocks

and the correlation between exchange rates and demand shocks are tested. Our main conclusion is consistent with the theory: exchange rate volatility does tend to increase the share of productive capacity located abroad and therefore contributes to world-wide economic integration. This contrasts with the view that volatile exchange rates impede international activity. Section V summarizes, compares our findings with those of previous studies, and concludes.<sup>10</sup>

Finally, we would like to emphasize that it is not the objective of this paper to survey or test the merits of alternative explanations for FDI flows. Our paper asks only when and whether real exchange rate variability may influence the pattern of FDI activity. This emphasis is meant to supplement and not meant to eclipse or diminish the range of important motives for FDI exposted elsewhere.<sup>11</sup> We focus purely on the effects of expected volatility of exchange rates, without emphasizing the direct effects of exchange rates on relative production costs and relative cross-country wealth patterns.<sup>12</sup>

## II. THE MODEL

In our model, investment responds to exchange-rate variability in two ways. First, producers can upscale or downscale existing production activities in the host country in response to expected market conditions. Second, the multinationals can acquire or merge with host-country producers. The latter category is the dominant form of recent foreign-

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<sup>10</sup>Existing empirical studies by Cushman (1985, 1988) on pooled United States bilateral FDI outflow data for the 1963-1978 period and inflow data for the period 1963-1986 concluded that exchange rate variability was positively correlated with both sets of flows. Bailey and Tavlas (1991), using quarterly data on aggregate real direct investment inflows for 1976:1-1986:1, were unable to find any adverse impact of either exchange rate variability or misalignment.

<sup>11</sup>The "OLI triumvirate" [Ethier (1986)] is based on: i) *ownership* advantages, including patents or management advantages held by the source country; ii) *locational* advantages, wherein the source or destination country features motivate international investment; or iii) *internalization* advantages wherein it is more advantageous for a firm to transact with its international subsidiary than to engage in arms length market activities.

<sup>12</sup>Relative wages are presented as incentives for FDI in the explanations based on "locational advantage". Froot and Stein (1992) argue that wealth effects of exchange rate changes may be the dominant channel for exchange rate level effects. Klein and Rosengren (1992) find support for the wealth channel in annual data for FDI flows into the United States.

direct investment activity in the United States. Mergers and acquisitions also subsume the construction by parent companies of new "greenfield" facilities.

Uncertainty, introduced in our model through variable exchange rates and stochastic foreign demand, influences total capacity choice and the share of total production capacity located overseas. The distributions of the stochastic exchange rates and foreign demand, including the correlations between these processes, are known to producers. Producer/ investors may be either risk-neutral or risk-averse.

**The Basic Set-up:** Our basic model is a two-period one in which a domestic firm produces only for a foreign market, with a combination of domestic capacity (with output exported) and foreign capacity, sited with demand. In the first period, the horizontally-integrated multinational decides on and commits to its capacity in its domestic and foreign plant locations. This investment in capacity represents the parent company's planned sales. The firm chooses productive capacity in both domestic and foreign locations either to maximize the present discounted stream of expected profits or the utility of those profits.

In period two, uncertainty in exchange rates and in demand are resolved: domestic and foreign facilities produce at capacity and take prices that clear the market. Investors repatriate their profits. Even though capacity is chosen in the first period, payments for investment capacity are made in the second period when revenues are realized.

Producers face an aggregate inverse demand function in the foreign country, denoted by  $P(q)$ . In our fixed factor model  $q$  represents the total production capacity of the multinational as well as (second-period) output since it will never pay to under-utilize capacity. By making all factors of production fixed, we eliminate the ability of the producers to buy, via foreign direct investment, the option of channeling production *ex post* to the more profitable location. Domestic and foreign country variables are denoted by  $d$  and  $f$  respectively. Thus,  $q_d$  and  $q_f$  are domestic and foreign output. Let  $\theta = q_f/q$  define the fraction of capacity overseas. Clearly  $0 \leq \theta \leq 1$ .



Foreign demand is subject to random real shocks, denoted by  $\delta$  with  $E(\delta) = 0$ . In our model, this corresponds to vertical movement in the foreign demand curve. Denote the variance of  $\delta$  by  $\sigma_\delta^2$ . The real exchange rate,  $e$ , is defined in terms of domestic currency per unit of foreign exchange, also is subject to random shocks. Thus, large  $e$  means a weak domestic currency. We choose units so that the expected value of the real exchange rate is unity, i.e.  $E(e)=1$ , and its variance is given by  $\sigma_e^2$ . Thus, we would expect (and assume) that  $\sigma_e^2 < 1$  since  $E(e) = 1$  and  $e \geq 0$ . The correlation coefficient between  $e$  and  $\delta$  is given by  $\rho = Cov(e, \delta) / \sigma_e \sigma_\delta$ , where  $Cov(e, \delta) = E(e\delta) = \overline{e\delta}$ .<sup>13</sup>

Although a variety of factors can explain the sign of the correlation between foreign demand and domestic real exchange rate shocks, consider the simple examples of foreign monetary and productivity shocks. An increase in the money supply in the foreign country would increase demand while raising foreign prices. With incomplete pass-through of the price changes into the bilateral exchange rate, this leads to a short-term real appreciation of the foreign currency and a real depreciation of the domestic currency. Under this scenario,  $\delta$  increases (i.e. it is positive) while  $e$  also rises, implying a positive value for  $\rho$ . Alternatively, if the foreign monetary shock leads to short-term exchange rate overshooting, the domestic currency would appreciate in real terms and  $\rho$  would be negative. Foreign demand shocks also can be caused by foreign productivity shocks occurring outside of the sector in which our firm is operating. If the price index over foreign goods is reduced without a compensating nominal exchange rate adjustment, the domestic currency appreciates in real terms and a positive  $\rho$  value is observed. The absolute size of these correlations could increase with wage rigidities.

Without loss of generality, we assume that capacity costs are equal to 1 per unit of domestic output and equal to  $ew_f$  per unit of output abroad, with  $w_f$  the foreign unit cost. Thus,  $ew_f$  is interpreted as the ratio of foreign to domestic production costs. Since ours is

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<sup>13</sup>If the distribution of  $e$  is highly skewed, it would be possible for  $\sigma_e^2 > 1$ . We preclude this, without loss of generality, in our opinion.

a short-term model, all production costs are embodied in the fixed factor, capacity. The profit function of the producer in period 2 is:

$$\pi(q_d, q_f, e, \delta) = e \cdot (P(q) + \delta) \cdot q - q_d - ew_f q_f \quad (1)$$

For simplicity we treat the foreign wage  $w_f$  as constant and the expected domestic-currency value of the foreign wage as identically equal to the domestic wage, with both equal to one. Assessed in period 1, the expected profits of the multinational, based on its capacity choice across domestic and foreign markets, are:

$$E(\pi) = q \cdot (P(q) - 1 + \overline{e\delta}) \geq 0 \quad (2)$$

where individual rationality requires expected profits to be nonnegative. Our first basic result follows directly from (2):

**Proposition 1:** *When exchange rate and foreign demand shocks are positively (negatively) correlated, expected product price is less (more) than expected marginal cost.*

One interesting implication of this result is that expected product price may be less than expected costs under profit-maximizing behavior and without dumping motives on the part of the producer. Thus, the dominance of positively correlated exchange rates and foreign demand shocks could lead to pricing behavior that is incorrectly interpreted as arising from dumping. Still unresolved from Proposition 1 is the relationship between these types of shocks and investment activities. For this point we consider two versions of the model: one where the producer is risk-neutral and one where the producer is risk averse. In both cases, the producer seeks to maximize expected profits (or the expected utility of profits) by his choice of total capacity and the location of capacity across countries.

## II.1 Risk Neutrality

In the case of risk neutrality, the effect of altered aggregate production levels on total expected profits is given by:

$$\frac{\partial E(\pi)}{\partial q} = P(q) + P'(q) \cdot q - 1 + \overline{e\delta} \quad (3)$$

and the first-order conditions for profit maximization are given by:

$$P(q) + P'(q) \cdot q = 1 - \overline{e\delta} \quad (4)$$

The left-hand side of (4) represents expected marginal revenues whereas the right-hand side terms represent (constant) marginal costs adjusted for the covariance between exchange-rate shocks and foreign demand shocks for the multinational product. Our second result follows from (4):

**Proposition 2:** *If the domestic firm is risk neutral and expected production costs are the same in domestic and foreign markets, then:*

- a) If  $\rho > 0$  ( $\rho < 0$ ), marginal costs exceed (are less than) expected marginal revenues and total output of the multinational expands (shrinks) relative to the deterministic case.*
- b) The firm is indifferent regarding the location of production facilities;*

Proposition 2 emphasizes that in this simple two-period model with risk neutrality, the multinational's investment in capacity today is a function of the correlation between the exchange rate used to value export earnings and the foreign demand for the multinational's product. Under risk neutrality, the total volume of production may be sensitive to the size and correlations between shocks, but the location of production facilities is not sensitive. The current model generates optimal production or capacity investment levels, but the parent company remains indifferent to the choice of home or domestic markets for location of the production facilities. The important point to keep in mind is that the stochastic nature of exchange rates and demand matter in our model *only to the extent that*

*these shocks are correlated.* Without risk aversion, and without expected relative wage or marginal cost effects across countries, foreign direct investment flows will not be significantly influenced by altered variability of exchange rates.

The correlation between export demand shocks and real exchange rate shocks is important in Proposition 2 and, in general, will be shown to be an important theoretical determinant of the location of investment facilities under risk aversion.

## **II.2 Risk Averse Producer-Investors**

Suppose that producers are risk-averse.<sup>14</sup> Assume that the expected utility of profits can be written as a function of expected profits and the variance of profits.

$$E(U(\pi)) = u(E(\pi), Var(\pi)) \quad (5)$$

This expected utility specification is justified if utility is quadratic or if the uncertainty induced in profits is normally distributed [Jarrow, 1988]. We will assume  $(e, \delta)$  are bivariate normal.<sup>15</sup> We also assume that  $E(U(\pi))$  is strictly concave, a somewhat stronger assumption. The variance of profits is given by:<sup>16</sup>

$$Var(\pi) = E\left(P(q)q(e-1) + (e\delta - \bar{e}\delta)q + q_f(1-e)\right)^2 = q^2 E\left((P(q) - \theta)(e-1) + (e\delta - \bar{e}\delta)\right)^2 \quad (6)$$

Using the properties of stochastic exchange rates and demand, this yields

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<sup>14</sup>It often is argued that firms are not risk averse. Dufey and Srinivasula (1984) review the weaknesses of these common arguments. First, risk aversion arises if corporate management seeks to avoid default risk and the costs of financial distress, where these costs rise with the variability of the net cash flows of the firm. Moreover, managers (and shareholders) may be personally heavily exposed to the risk of variable firm profits and thereby would attempt to eliminate this risk. Rodriguez (1981) provides supporting evidence on management attitudes and behavior. Another common argument against firm risk aversion is based on the Modigliani-Miller theorem. This theorem implies that whatever the firm can do (in terms of hedge activities), investors can do: if exchange risk is to be hedged, it need not be done by the firm. But, this argument is weakened by higher impediments to efficient hedging by individuals, including firm-level access to lower cost hedges and informational asymmetries across managers and shareholders about firm-level exposure to risk.

<sup>15</sup>Note that we stated earlier that  $E(e)=1$  and  $e$  is non-negative. The exchange rate process is assumed to be centered about one rather than about zero. Because of normality, we have:

$$E(e\delta) = \rho\sigma_e\sigma_\delta, \quad E(e^2\delta) = 2\rho\sigma_e\sigma_\delta, \quad \text{and} \quad E(e^2\delta^2) = 2\rho^2\sigma_e^2\sigma_\delta^2 + (1 + \sigma_e^2)\sigma_\delta^2.$$

<sup>16</sup>Equation (6) is derived by taking the expected value of the squared difference between profits as defined in equation (1) and expected profits as presented in equation (2).



$$Var(\pi) = q^2 \left( \sigma_e^2 (P(q) - \theta)^2 + 2(P(q) - \theta) \rho \sigma_e \sigma_\delta + \rho^2 \sigma_e^2 \sigma_\delta^2 + (1 + \sigma_e^2) \sigma_\delta^2 \right) \quad (7)$$

where  $\theta = q_f/q$ .

Using equations (5), (2) and (7), one can determine the period one investments in domestic and foreign capacity (actually  $q$  and  $\theta$ ) that will maximize investor utility. The goal, maximizing (5) subject to  $q \geq 0, 0 \leq \theta \leq 1$  and (2), represents a constrained optimization problem for which the Lagrangian is:

$$L = E(U(\pi)) + \lambda q + \nu \theta + \mu(1 - \theta) + \chi(P(q) - 1 + \overline{e\delta}) \quad (8)$$

where  $\lambda$ ,  $\nu$ ,  $\mu$ , and  $\chi$  are the multipliers on the respective constraints. Consider the case where (2) is non-binding and thus  $\chi=0$ . The first-order conditions depend on whether optimal  $q$  and/or  $\theta$ , denoted by "\*", are at the boundaries:

$$q^* > 0, 0 < \theta^* < 1 \quad \Leftrightarrow \quad \frac{\partial E(U(\pi))}{\partial q} = 0, \quad \frac{\partial E(U(\pi))}{\partial \theta} = 0 \quad (9a)$$

$$q^* > 0, \quad \theta^* = 0 \quad \Leftrightarrow \quad \frac{\partial E(U(\pi))}{\partial q} = 0, \quad \frac{\partial E(U(\pi))}{\partial \theta} < 0 \quad (9b)$$

$$q^* > 0, \quad \theta^* = 1 \quad \Leftrightarrow \quad \frac{\partial E(U(\pi))}{\partial q} = 0, \quad \frac{\partial E(U(\pi))}{\partial \theta} > 0 \quad (9c)$$

$$q^* = 0 \quad \Leftrightarrow \quad \frac{\partial E(U(\pi))}{\partial q} < 0 \quad (9d)$$

where the basic regularity condition (strict complementarity) is assumed to apply.

Assume  $\gamma = -2U_2/U_1 > 0$  is constant where  $U$  is defined in (5) and the  $U_i$  denote the respective first derivatives. Then, in (9), note that

$$\frac{\partial E(U(\pi))}{\partial q} = U_1 \frac{\partial E(\pi)}{\partial q} + U_2 \frac{\partial Var(\pi)}{\partial q} = U_1 (A - P'(q)B) \quad (10a)$$

$$\frac{\partial E(U(\pi))}{\partial \theta} = U_1 \frac{\partial E(\pi)}{\partial \theta} + U_2 \frac{\partial Var(\pi)}{\partial \theta} = U_1 B \quad (10b)$$

where

$$A = P(q) + P'(q)q - 1 + \overline{e\delta} - \frac{\gamma}{q} \text{Var}(\pi) \quad (10c)$$

$$B = \gamma q^2 \left( (P(q) - \theta) \sigma_e^2 + \overline{e\delta} \right) \quad (10d)$$

From the assumed strict concavity of  $E(U(\pi))$ , a solution to (9) and (10) exists, although of course it may be trivial ( $q=0$ ). Note that these first-order conditions differ primarily in the  $A$  term in equation (10a). Therefore, the following results hold:

**Lemma 1:** *Assuming regularity conditions hold and equation (2) holds but is non-binding, for any optimal  $q > 0$  the following applies:*

$$P(q) - \theta + \rho \frac{\sigma_\delta}{\sigma_e} \begin{cases} = 0 \Leftrightarrow q_d, q_f > 0 \\ < 0 \Leftrightarrow q_f = 0 \\ > 0 \Leftrightarrow q_d = 0 \end{cases} \quad (11)$$

The basic interpretation of this result is that, with even a small degree of risk aversion, the parent company is not indifferent to the location of facilities, even when the expected unit costs of production are equal across facilities. Foreign direct investment flows will be influenced by the expected variability of real exchange rates.

It is important to remember that  $\rho$ ,  $\sigma_e$ , and  $\sigma_\delta$  are exogenous to the firm. Based on these characteristics of the distributions of the  $e$ 's and  $\delta$ 's, the firm chooses  $q_d$  and  $q_f$  (both of which may be zero). Lemma 1 leads directly to the following corollary:

**Corollary 1:** *Under the conditions of Lemma 1 with  $q > 0$ , the following must hold:*

$$\begin{aligned} & \left. \begin{aligned} q_f = 0 &\Rightarrow 1 < A \\ q_d > 0 &\Rightarrow 0 \leq A \end{aligned} \right\}, \begin{cases} A \leq 1 \Rightarrow q_f > 0 \\ A < 0 \Rightarrow q_d = 0 \end{cases} \\ & \text{where } A = -\rho \frac{\sigma_\delta}{\sigma_e} (1 - \sigma_e^2) \end{aligned} \quad (12)$$

Proof: Add equation (11) and equation (2) to derive equation (12).

There are a number of implications of Corollary 1. First, with  $e$  and  $\delta$  positively correlated, foreign demand is high precisely when the domestic currency is weak. By locating production facilities overseas, the producer minimizes the variance of expected profits and increases expected utility. Thus, the expected utility of profits is maximized by locating all production in the foreign country.

Second, when there is only exchange rate uncertainty and no demand uncertainty (or when these shocks are orthogonal), then it is always desirable to locate some production overseas, i.e.  $q_f > 0$ . This may be the case if exchange rates are determined purely by short-term speculation in financial markets and are unrelated to other market fundamentals. Under risk aversion, there always will be production located abroad, in contrast to the risk neutrality case where the location choice is indeterminate.

Third, if demand and exchange rate shocks are modestly negatively correlated it will be desirable to have some domestic production and not place all of one's capacity offshore.

Corollary 1 also states that when specific patterns in domestic and foreign investment activity are observed, there are relationships between exchange rate and foreign demand shocks that must be satisfied. For example, if no capacity is located offshore, exchange rates and foreign demand shocks must be negatively correlated. If there is at least some capacity sourced at home, then these shocks must be positively correlated.

### **II.3 Comparative Statics:**

Having defined the condition for optimal choice of  $q_d$  and  $q_f$ , we now turn to the question of how these optimal choices are affected by the scale of the uncertainty in exchange rates and demand and by the covariance structure between these shocks.

**Proposition 3:** Assume at an optimal  $q$ , that  $q_d, q_f > 0$ . Then:

$$\frac{\partial \theta^*}{\partial \sigma_e} > 0 \quad \frac{\partial q^*}{\partial \sigma_e} < 0 \quad (13)$$

Proof: See Appendix.

This result states that the greater the variability of exchange rates, the larger the share of capacity located offshore, even though overall capacity declines. We cannot conclude whether or not the absolute level of FDI rises or falls. Implicit in this proposition is the fact that exchange rate and demand shocks are negatively correlated (Corollary 1); otherwise  $q_d = 0$ . This is somewhat as expected since profits, as opposed to just revenues, are exposed to exchange rate fluctuations when foreign investment occurs.

Further comparative statics results emerge with some restrictions on the form of the demand function:

**Proposition 4:** Assume at an optimal  $q$ , that  $q_d, q_f > 0$ . Further assume that demand is not excessively convex, i.e.  $P'(q) + P''(q)q < 0$  for all  $q > 0$ . Then:

$$\frac{\partial \theta^*}{\partial \rho} > 0 \quad (14)$$

Proof: See Appendix.

By assumption  $\rho < 0$  from Corollary 1. A negative  $\rho$  means that foreign demand is high ( $\delta$  is large) precisely when the domestic currency is strong. But, as this relationship erodes as  $\rho$  becomes larger and we move closer to the region of  $\rho > 0$  where all production is foreign. Thus, as  $\rho$  rises,  $\theta$  rises. When  $0 < \theta < 1$ , an increase in exchange rate variability which would otherwise tend to increase the share of foreign investment can be offset by an increase in the absolute value of the covariance between demand shocks and exchange rate shocks.



## II.4 Testable Implications

Our model of the implications of real exchange rate variability yields clear predictions for bilateral flows of foreign direct investment under fixed productive factors. Under risk neutrality, FDI share is not expected to be correlated with variability measures. By contrast, with just a small degree of risk aversion and if  $\rho \geq 0$ : positive FDI always occurs (Corollary 1). This share of total capacity located abroad would be unresponsive to exchange rate variability in this regime only if all capacity already is located on foreign soil. With the share of FDI in total investment bounded away from zero and one and  $\rho \leq 0$ , the FDI share increases as exchange rate variability rises (Proposition 2). Furthermore, as long as demand is not excessively convex, the FDI share increases as the correlation between exchange rate and real demand shocks rises (Proposition 3).

Defining a source country by the index  $i$  and a destination market by the index  $j$ , these theoretical propositions give rise to the following testing equation:

$$\theta_t^j = \beta_0^i + \beta_1^i \sigma_{e,t}^j + \beta_2^i \sigma_{\delta,t}^j + \beta_3^i \rho_t^j + \beta_4^i e_t^j + \beta_5^i y_t^j + \mu_t^i \quad (15)$$

where the share of production capacity from the source country  $i$  located in the destination country  $j$  is a function of: (i) the volatility of the bilateral real exchange rate,  $\sigma_{e,t}^j$ , which is expected to enter with a positive coefficient  $\beta_1^i$ ; <sup>17</sup> (ii) the volatility of real destination market demand,  $\sigma_{\delta,t}^j$ , for which the coefficient  $\beta_2^i$  is ambiguously signed; (iii) the correlation between the real exchange rate and real destination market demand,  $\rho_t^j$ , which is expected to enter with a positive coefficient  $\beta_3^i$ ; and (iv) the real exchange rate  $e_t^j$ , which is expected to enter with a negative coefficient  $\beta_4^i$ . We also include in the regressions (v) destination market demand,  $gdp_t^j$ , although the sign and significance is not determined in our model.

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<sup>17</sup> Assuming some risk aversion.

### III. THE DATA

These theoretical predictions are tested using bilateral foreign direct investment activity between the United States and the United Kingdom, Japan and Canada. The country choices for bilateral partners is partially motivated by data availability and partially motivated by the importance of these countries to the United States in foreign-direct-investment flows. In 1990, for example, the United Kingdom, Japan and Canada together accounted for approximately 55 percent of all FDI into the United States, both when measured in terms of parent company identities or in terms of ultimate beneficial owners.

Our model treats foreign-direct-investment as total investment or capacity location choice by the parent in a subsidiary at any point in time. We use flow data on bilateral investments, with the foreign direct investment data drawn from United States balance-of-payments tables. For inflows into the United States, these data capture the increase in the book value of equity in United States businesses or assets deemed under foreign control. An analogous definition applies to outflows originating in the United States and invested abroad.<sup>18</sup> In order to minimize estimation problems stemming from the major step-up in the early 1970s of interest in the United States as a target for foreign investment [Caves (1989)] our sample period begins in 1978. The data is quarterly, from 1978:I through 1991:IV. All data sources are provided in Table 1.

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<sup>15</sup>These balance-of-payments data are subject to a well-known short-coming: reinvested earnings of foreign subsidiaries, as invested wealth by the parent, are not appropriately measured. This omission is more of a problem in the late 1970s than it is in the 1980s, when reinvested earnings were a much smaller portion of bilateral equity positions [Lipsey (1992)].

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**Table 1: Data Sources****Foreign Direct Investment Series**

$q^{ij}$ : Bilateral foreign direct investment flows between the United States and Canada, Japan, and the United Kingdom. Source: *The Survey of Current Business*.

**Country Investment Series**

$q_i$ : Aggregate investment by each country  $i$  are non-seasonally adjusted data.

United States: Non-Residential Fixed Investment, source: the *National Income and Product Accounts*.<sup>a,b</sup>

Japan: Gross Fixed Capital Formation, source: *Economic Planning Agency* (of Japan).

United Kingdom: Gross Fixed Capital Formation, source: Central Statistical Office, data reported in *Economic Trends 1992 Supplement*

Canada: Gross Fixed Capital Formation.

**Bilateral Exchange Rates**

Each bilateral real exchange rate is defined as the product of the source country nominal bilateral exchange rate multiplied by the destination country price index and divided by the source country price index. The nominal exchange-rate data are from the *International Financial Statistics* (IMF) and the price indices are CPI data drawn from the *OECD*.

**Real GDP**

Nominal GDP for each country  $i$ , deflated by the respective CPI series, with data drawn from the *International Financial Statistics* (IMF) and the *OECD*, respectively.

a: The quarterly data are from "United States International Transactions Tables", by the United States Department of Commerce. The series are "Private Foreign Direct Investment into the United States" and "United States Direct Investment, Private Assets Abroad".

b: We have also conducted all of the regression analysis using a denominator of domestic investment net of total net foreign direct investment inflows, in order to adjust for the foreign source investment included in the total domestic investment measures. None of our results are significantly altered by this adjustment, so we report only the results using total investment in the denominator.

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***Construction of FDI Shares:*** The shares  $\theta$  are constructed by dividing the FDI outflows from a source country to a destination market by a measure of investment activity in the source country. The two-way bilateral flows are between the United States and Canada, Japan, and the United Kingdom. While this measure captures the flavor of our model, there are limitations in this data. The theory considers movements in FDI relative to domestic investment. However, for these purposes the appropriate measure of domestic

investment is not aggregate source country investment but instead is investment in the total new capacity of export-oriented production firms. Unfortunately this measure is unavailable. The second shortcoming of our data is that the foreign direct investment data miss important forms of reinvestment of earnings and tend to understate total foreign investment.

***Construction of volatility and correlation measures:*** For each of the bilateral real exchange rates  $e^{ij}$  used, both the levels and distributions of each real exchange rate are constructed from the vantage point of the respective source countries. The measure of exchange rate volatility is constructed as the standard deviation of the exchange rate over an interval, normalized by the mean level of the exchange rate within the interval. We construct this measure over rolling samples of twelve quarters of data, prior to and inclusive of each period  $t$ . This measure  $\sigma_e^{ij}$  incorporates both the "predictable" and "unpredictable" components of exchange rate movements. It is particularly informative when exchange rates are close to random walks.

An analogous procedure also is used to construct a proxy for real demand variability for each destination country,  $\sigma_{s,t}^j$ . In addition, the real exchange rate and real GDP series (about their respective sample means) are correlated across rolling samples of data. The resulting correlation between these residual series is reported at each time  $t$  and is denoted by  $\rho^j$ . The descriptive statistics for each of the volatility and correlation measures are presented in Table 2.

The US\$/Can\$ real exchange rates exhibited the smallest amount of variability, at roughly one third the size of the dollar/yen and dollar/pound levels. The variability of the dollar/yen exchange rates increased significantly in the 1985 to 1990 period as compared with levels in 1978 to 1984. Negative correlations between exchange rates and foreign real GDP generally are observed from the Japanese perspective for its assessment of the



United States as a destination country for investments and for Japanese products.<sup>19</sup> Such negative correlations also are observed from the perspectives of the United Kingdom and Canada in assessing flows to the United States in the second half of the 1980s. The United States flows to Canada were primarily under a regime of negative correlations in the late 1970s and early 1980s. This could suggest that monetary shocks in the United States markets or possibly fiscal shocks in foreign markets were dominant during this period.

Table 2	Descriptive Statistics on Variance and Covariance Measures (period averages)						
	normalized std. dev. of real exchange rate		correlation: real exchange rate and destination market GDP shocks		normalized std. dev. of real destination market GDP		destination market country
	78-84	85-91	78-84	85-91	78-84	85-91	
yen/US\$ real exchange rate	0.094	0.111	-0.397 (89.3%)	-0.396 (85.7%)	0.038	0.037	United States
pound/US\$ real exchange rate	0.098	0.093	0.107 (42.9%)	-0.311 (82.1%)	----		United States
Can\$/US\$ real exchange rate	0.029	0.035	0.109 (46.4%)	-0.123 (67.9%)	----		United States
US\$/yen real exchange rate	0.097	0.109	0.025 (53.6%)	0.144 (42.9%)	0.081	0.079	Japan
US\$/pound real exchange rate	0.098	0.089	0.145 (28.6%)	0.237 (42.9%)	0.035	0.042	United Kingdom
US\$/Can\$ real exchange rate	0.030	0.035	-0.335 (96.4%)	0.199 (46.4%)	0.051	0.046	Canada
numbers in parentheses reflect, respectively, the share of $\rho < 0$ out of a total of 28 observations in the 1978 to 1984 sample and 24 observations in the 1985 to 1991 sample.							

**Stationarity Properties of the Data:** In Table 3 we provide the p-values of augmented Dickey-Fuller (ADF) tests performed over the data used in the empirical work. We can reject non-stationarity for all ratios constructed for FDI activity with the exception of the shares of United States investment into Japan and into the United Kingdom.

<sup>19</sup>This is interesting when considered in the context of Proposition 1. Recall that one interpretation of Proposition 1 is that the existence of *positive* correlations between exchange rates and foreign demand shocks may inappropriately lead to dumping charges. Since the Japanese observe *negative* correlations, our model does not suggest that evidence provided in support of dumping charges would be misconstrued.

Table 3		<b>p-values from Augmented Dickey Fuller tests for Unit Roots.</b>			
		Tests performed using constant & no trend (c), constant and trend (t), neither constant or trend (n), and with range of lag lengths. UR = Unit Root			
	description	United States [#obs.=52]	Canada [#obs.=52]	Japan [#obs.=52]	United Kingdom [#obs.=52]
FDI share of US into destination		n.a.	1c: p=5 Reject UR	1c: p=1 Reject UR	4c: p=5 Reject UR
FDI of source into US as source share		n.a.	5c: p=5 Reject UR	3t: p>10 Cannot Reject	4c: p>10 Cannot Reject
$\rho$ (i,j)	US\$/destination	n.a.	4t: p>10 Cannot Reject	4n: p=5 Reject UR	4n: p=1 Reject UR
$\rho$ (i,j)	destination/US\$	n.a.	4n: p=1 Reject UR	4n: p=10 Reject UR	6t: p>10 Cannot Reject
$\sigma_e$ (i,j)	US\$/destination	n.a.	1c: p=1 Reject UR	1c: p=1 Reject UR	3c: p>10 Cannot Reject
$\sigma_e$ (i,j)	destination/US\$	n.a.	1c: p=1 Reject UR	1c: p=1 Reject UR	3c: p>10 Cannot Reject
real GDP volatility		4c: p=5 Reject UR	4t: p=5 Reject UR	4c: p>10 Cannot Reject	5c: p>10 Cannot Reject
real exchange rate	US\$/destination	n.a.	3c: p>10 Cannot Reject	1c: p>10 Cannot Reject	6c: p>10 Cannot Reject
real exchange rate	destination/US\$	n.a.	3c: p>10 Cannot Reject	1c: p>10 Cannot Reject	6c: p>10 Cannot Reject
real GDP		5t: p>10 Cannot Reject	6t: p>10 Cannot Reject	4t: p>10 Cannot Reject	4t: p>10 Cannot Reject
The p-values reported correspond to the highest probability of a unit root over the range of tests performed using the constant and trend, constant and no trend, and neither constant or trend, and at various lag lengths. In this way, we have a conservative assessment of unit root rejections.					

With the possible exception of the exchange rate and GDP series, we do not have unit root problems for the right hand side (RHS) variables included in regressions for bilateral outflows from the United States or inflows into the United States from Canada. However, inflows into the United States from Japan and from the United Kingdom may be nonstationary series.<sup>20</sup> While this is important since regression inference is severely weakened if stationary series are regressed against nonstationary series, caution must be exercised in any event because the test for nonstationary are biased in against rejecting unit roots. Thus, we account for the possibility the ADF tests yield incorrect results by following regression procedures suggested by Stock (1992): those right hand side

<sup>20</sup>The ADF test is being applied to small samples, generally 52 observations, and, as shown by Stock (1992) is biased against rejection of unit roots in the data.

variables that may have unit roots are entered both in level and first difference format into the regressions. Those dependent variables that may have unit roots are tested alternatively in level and first difference format.

#### **IV. RESULTS OF EMPIRICAL ANALYSIS**

The implications of exchange rate and demand patterns for the share of investment activity located overseas are studied via estimates of regression equation (15).<sup>21</sup> For each of the directions of bilateral investment, we also tested whether the FDI shares responded differentially to the volatility measures across regions of positive and negative value of  $\rho$ . If there was a differential response, the regression results are reported.<sup>22</sup>

As shown in Table 4, exchange rate variability had a positive and statistically significant effect on four of the six series of bilateral FDI shares: real exchange rate variability increased the share of total United States investment capacity located in Canada and in Japan, and increased the share of Canadian and United Kingdom investment located in the United States. These results are consistent with the predictions of Proposition 3. We did not find evidence that the effects of real exchange rate volatility on investment significantly differed across periods when there were positive and negative correlations between exchange rate and demand shocks. Of the two series on bilateral FDI shares in

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<sup>21</sup>The ordinary least squares regressions contain seasonal dummy variables and serial correlation adjustments. The coefficients on autoregressive and seasonal terms are not reported in the summary tables but are available from the authors upon request. Where appropriate, heteroskedasticity and serial correlation problems are corrected using Newey-West procedures. The models were chosen based upon the Breusch-Godfrey test for serial correlation, various versions of White's test for heteroscedasticity, and an ARCH test of four lags. If the models passed all of these tests, their inference is accepted. If not, the models were estimated where appropriate by a GMM procedure with a Newey-West correction for serial correlation. As required, the regression equation is modified as required to account for nonstationarities in the data by also entering the potentially first order integrated series into the regressions in first differences.

<sup>22</sup>We do not control our results for changes in tax laws: such laws have not been found to be significant determinants of real bilateral FDI flows of the United States. One could consider, for example, the implications of the 1981 US tax cut, which provided for accelerated depreciation. This policy change remained in place through the end of 1986. Another important US tax policy change is the Repeal of the General Utilities Rule in 1987. Slemrod (1989) did not find these tax changes were significant for US inward bilateral FDI flows. Klein and Rosengren (1992) had consistent findings, and these tax changes did not alter the pattern of exchange rate level effects on bilateral investments.



which exchange rate volatility was not statistically significant, the regression equations were subject to econometric problems. The series of Japanese FDI shares into the United States is potentially nonstationary and first differences of this dependent variable were used in the regressions. The share regression for United States FDI into the United Kingdom was subject to problems of heteroskedasticity: the reported corrections using Newey-West procedures eliminated any observed statistical significant over the right-hand side variables.

Our theoretical work did not imply clear predictions about the effect of variability of destination market demand conditions on FDI shares. This force was statistically significant only for Japanese investment into the United States: the higher was United States real GDP volatility, the smaller was the share of Japanese investment sited in the United States.

Proposition 4 stated that, under particular restrictions about the structure of demand, an increase in the covariance between destination market demand shocks and real exchange rate shocks would lead to an increase in the FDI share. This direction of response is supported for all outflows of FDI from the United States and for Canadian FDI into the United States. However, the results were statistically distinct from zero only for two of the six bilateral flow shares.

Exchange rate levels and first differences in exchange rates also enter into the regression equations. These variables have been found to be highly significant in previous empirical studies of real FDI activity tested over annual data. By most theoretical arguments, a domestic currency depreciation is expected to decrease source country foreign direct investments abroad. The basic arguments fall into two camps: either real depreciations raise the relative price of foreign productive resources or increase the relative competitiveness of foreign competitors bidding for the same production site. It should be noted that these arguments apply to levels of FDI activity and require additional assumptions before they also pertain to the *share* data as used in our regressions.



Table 4: FDI Outflows as a Share of Source Country Investment

$$\theta_t^{ij} = \beta_0^i + \beta_1^i \sigma_{e,t-1}^{ij} + \beta_2^i \sigma_{\delta,t-1}^j + \beta_3^i \rho_{t-1}^{ij} + \beta_4^i e_{t-1}^{ij} + \beta_5^i y_{t-1}^j + \mu_t^i$$

RHS variables	Direction of Bilateral FDI as Share of Source Country Investment							
	Can. FDI into the US	U.S. FDI into Canada	UK FDI into the United States <sup>a</sup>		US FDI into the UK <sup>+</sup>	Japan FDI into the United States <sup>a</sup>		US FDI into Japan
$\sigma_e$	1.58* (.586)	.225** (.114)	1.525* (.440)		-.354 (.378)	-.027 (.022)	.012 (.039)	.037** (.021)
D* $\sigma_e$	-.567 (.932)	---						-.021 (.020)
$\Delta \sigma_e$		---	0.637 (1.24)	-.492 (.962)	-.164 (.266)	-.114* (.040)		
D* $\Delta \sigma_e$		---		-.198 (.497)				
$\sigma_{\delta_-}$	.851 (1.07)	.394 (.396)	-0.454 (.860)		.819 (.766)	-.270* (.050)	.161 (.334)	.091 (.097)
$\Delta \sigma_{\delta_-}$			-1.140 (2.61)	-.937 (3.82)	-.687 (.516)	.027 (.197)		.131 (.273)
$\rho$	.072* (.030)	.008 (.010)	-0.005 (.020)	-.012 (.021)	.012 (.020)	-.003 (.009)	-8E-4 (.005)	.001 (.005)
D* $\rho$	-.128** (.065)			.033 (.046)				.013** (.008)
$\Delta \rho$			-0.055 (.044)	-.229* (.090)				
D* $\Delta \rho$				.401* (.138)				
$e$	-.077 (.239)	-2E-4 (.070)	-0.094 (.113)		-.023 (.024)	-6E-6 (8E-5)		-2.99* (1.44)
$\Delta e$	.551** (.298)	-.128 (.117)	0.413 (.286)	-.082 (.241)	.009 (.020)	7.6E-5 (8.5E-5)	5E-5 (9E-5)	3.00** (1.73)
$y^j$	3E-4 (9E-3)	-2E-4 (4E-4)	0.001* (.000)		-.002 (.001)	8E-5* (2.5E-5)		2E-7* (7E-8)
$\Delta y^j$	5E-4 (4E-3)	2E-3* (9E-4)	1.8E-3 (.002)	1.5E-3 (1.2E-3)	.001 (.001)	6E-5 (1E-4)	5E-5 (15E-5)	9E-8 (8E-7)
Adj. R <sup>2</sup>	.176	.068	.267	.322	-.062	.636	.272	.337
D.W.	2.17	2.04	2.09	2.29	1.94	1.99	2.14	2.04
F-statistic	1.64	1.26	2.03	2.24		6.25	2.64	2.40
#observation	43	47	46	43	48	46	45	45

a/ first difference of the dependent variable.

Standard errors reported below parameter estimates. "D" indicates a dummy variable for periods with  $\rho > 0$ .  $\Delta$  indicates the first difference of a variable.

Constants, seasonal dummy variables and AR and MA adjustments are not reported.

\* denotes significance at the 5% level; \*\* denotes significance at the 10% level.

<sup>+</sup> indicates that the Newey West procedure was applied.

In our tests using quarterly data, the exchange rate levels entered with the expected sign in all regressions: exchange rate depreciations of the source country currency lead to a reduction in investment flow shares to foreign markets. However, these effects generally were neither large or statistically significant. In part, the weak role of exchange rate levels may be attributable to the potential nonstationarity of quarterly exchange rate series. It also may be attributable to a valuation effect: although the absolute level of FDI may decline in response to a domestic currency depreciation, the domestic currency value of that FDI at least partially increases due to the change in the exchange rate. Our findings are consistent with Lipsey's (1992) interpretation of the potential effects of exchange rate changes on investment. Lipsey argues that a depreciation of the domestic currency does make foreign facilities more expensive, and probably leads to a reduction in demand for physical investment abroad. However the overall impact on the value of foreign direct investment requires a high elasticity of demand for investment assets. Our results suggest that either the quarterly movements in exchange rate do not matter for FDI flows, or the elasticities of investment demand are not large enough so that domestic currency depreciations actually reduce investment flows abroad.

#### IV. CONCLUSIONS

This paper has contributed to our understanding of the real effects of variable exchange rates in several dimensions. First, we have argued that there are two classes of models that link real exchange rate *variability* to international investment activity. The first class of model relies on the argument that producers engage in international investment diversification in order to achieve *ex post* production flexibility and higher profits in response to shocks. This argument is relevant to the extent that *ex post* production flexibility is possible within the window of time before the realization of the shocks. This suggests that the production flexibility argument is less likely to pertain to short term volatility in exchange rates than to realignments over longer intervals.

Since many of the discussions of the merits of fixed versus flexible exchange rate regimes emphasize the implications of short term volatility, the group of arguments based on the risk-taking characteristics of producers are more likely to be most relevant for investment activity in domestic and foreign markets. We use a simple model to illustrate the linkage between exchange rate variability and the decision by producers to locate production facilities on domestic versus foreign shores. Exchange rate variability is expected to have real effects on the share of domestic investment resources channeled abroad in a limited set of circumstances. If investors are risk neutral, the model does not predict any statistical relationship between exchange rate volatility and the allocation of production facilities between domestic and foreign markets. But, if there is risk aversion among producers, exchange rate volatility may expand the share of investment resources located offshore.

We used data for two-way bilateral foreign direct investment flows between the United States, and Canada, Japan, and the United Kingdom to explore the empirical content of the theoretical propositions. The empirical results were consistent with the theory: exchange rate volatility tended to stimulate the share of investment activity located on foreign soil. We did not find evidence that there were statistically different effects of exchange rate volatility on investment shares when one distinguishes between periods where real or monetary shocks dominate exchange rate activity. We also found that real depreciations of the source country currency were associated with reduced investment shares to foreign markets, but these results generally were statistically insignificant in our quarterly data.

The theoretical work concluded that even though the share of total investment located abroad will, under certain conditions, rise as exchange rate volatility increases. But, this does not necessarily imply that exchange rate volatility depresses aggregate investment activity in the domestic economy. In order to conclude that domestic aggregate investment declines, one must show that the increase in domestic outflows is not offset by

a rise in foreign inflows. In the aggregate United States economy, it is unlikely that exchange rate volatility has had large contractionary effects on overall investment. This is substantiated by the findings of Campa and Goldberg (1993), in which exchange rate volatility did not significantly influence investment in United States manufacturing nondurables sectors.<sup>23</sup> Although exchange rate volatility did tend to depress investment in manufacturing durables sectors, these effects were quantitatively quite small. Taken together, these studies suggest that exchange rate volatility can contribute to the internationalization of production activity without substantially depressing economic activity in the home market. This conclusion is important for arguments about the appropriate choice of exchange rate regime: it is incorrect to assume that the selection of a flexible exchange rate system will lead to depressed economic activity. If the lessons drawn from United States investment flows can generalize, the results suggest that the choice of a controlled exchange rate regime does not clearly provide an environment more conducive to economic growth. Even if other empirical studies conclude that exchange rate volatility depresses real export activity, this does not contradict our conclusions. Exchange rate volatility can spur an increase in international capital flows that can substitute for international trade in goods without depressing overall economic activity.

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<sup>23</sup>See also Goldberg (1993).



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## Appendix I

### Proof of Proposition 2:

To prove this proposition we totally differentiate the first-order condition (9a) to obtain:

$$\begin{bmatrix} \frac{\partial^2 EU}{\partial q^2} & \frac{\partial^2 EU}{\partial q \partial \theta} \\ \frac{\partial^2 EU}{\partial \theta \partial q} & \frac{\partial^2 EU}{\partial \theta^2} \end{bmatrix} \begin{bmatrix} \frac{dq}{dx} \\ \frac{d\theta}{dx} \end{bmatrix} = \begin{bmatrix} -\frac{\partial^2 EU}{\partial q \partial x} \\ -\frac{\partial^2 EU}{\partial \theta \partial x} \end{bmatrix} \quad (\text{A-1})$$

where  $EU = E[U(\pi)]$  and  $x$  can be  $\rho$ ,  $\sigma_e$ , or  $\sigma_\delta$ . Cramer's rule is applied to determine  $\partial\theta/\partial x$  and  $\partial q/\partial x$ . We know that the left-hand side matrix of (A-1) is negative semi-definite, and thus its determinant is positive, since  $EU$  is strictly concave by assumption. Since at an optimum  $A=B=0$  (from eq. 10a and 10b), and eliminating the minus sign of the right-hand-side vector, the following holds

$$\text{sign} \frac{d\theta}{dx} = -\text{sign} \begin{vmatrix} \frac{\partial(A-P^*B)}{\partial q} & \frac{\partial(A-P^*B)}{\partial x} \\ \frac{\partial B}{\partial q} & \frac{\partial B}{\partial x} \end{vmatrix} = -\text{sign} \left( \frac{\partial A}{\partial q} \frac{\partial B}{\partial x} - \frac{\partial A}{\partial x} \frac{\partial B}{\partial q} \right) = -\text{sign}(\Delta) \quad (\text{A-2a})$$

$$\text{and } \text{sign} \frac{dq}{dx} = -\text{sign} \left( \frac{\partial B}{\partial \theta} \frac{\partial A}{\partial x} - \frac{\partial A}{\partial \theta} \frac{\partial B}{\partial x} \right) \quad (\text{A-2b})$$

Note that

$$\frac{\partial A}{\partial q} = 2P'(q) + P''(q)q - \gamma\sigma_e^2[1 + \sigma_e^2(1 + \rho^2)] < 0 \quad (\text{A-3a})$$

$$\frac{\partial B}{\partial q} = \gamma q^2 P'(q) \sigma_e^2 < 0 \quad (\text{A-3b})$$

$$\frac{\partial A}{\partial \theta} = 2\gamma q \sigma_e^2 \left[ P(q) - \theta + \rho \frac{\sigma_\delta}{\sigma_e} \right] = 0 \quad (\text{A-3c})$$

$$\frac{\partial B}{\partial \theta} = -\gamma q^2 \sigma_e^2 < 0 \quad (\text{A-3d})$$

$$\frac{\partial A}{\partial x} = \begin{cases} \sigma_e \sigma_\delta + 2q\gamma\rho\sigma_\delta^2(1 - \sigma_e^2) & , \quad x = \rho \\ \rho\sigma_\delta - 2q\gamma\sigma_e\sigma_\delta^2(1 + \rho^2) \leq 0 & , \quad x = \sigma_e \\ \rho\sigma_e - 2q\gamma\sigma_\delta(1 + \sigma_e^2(1 + \rho^2)) \leq 0 & , \quad x = \sigma_\delta \end{cases} \quad (\text{A-4 a,b,c})$$

$$\frac{\partial B}{\partial x} = \begin{cases} \gamma q^2 \sigma_e \sigma_\delta > 0 & , \quad x = \rho \\ -\gamma q^2 \rho \sigma_\delta \geq 0 & , \quad x = \sigma_e \\ \gamma q^2 \rho \sigma_e \leq 0 & , \quad x = \sigma_\delta \end{cases} \quad (\text{A-4 d,e,f})$$

The sign of (A-4a) is indeterminate; the sign of the other equations in A-4 follow from Corollary 1 (i.e  $\rho \leq 0$ ), Lemma 1, and the assumptions of the proposition. Only  $d\theta/dx$  for  $x = \sigma_e$  can be definitively signed.

Proof of Proposition 3:

Using the above notation it is easy to demonstrate that  $\frac{\partial \Delta}{\partial \rho} \geq 0$  and  $\Delta|_{\rho=0} < 0$ . Since  $\rho \leq 0$ , this implies  $\Delta < 0$  which implies  $\frac{d\theta^*}{d\rho} > 0$ .













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